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Langmuir Probe Microprocessor System

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The microprocessor data acquisition and control system for the grande boîte is programmed for real time measurement of the electron density and temperature profiles.

A block diagram of the system is shown in Fig. 1. After the program is initialized (the initialization procedure is described in Appendix A), a time sequence of events is as follows:

1) The μP senses the position of the probe and compares it to the desired position given by the initialization procedure.

2) The μP sends a command to the probe motor via the Probe Position Control Unit to move the probe to the desired position.

3) The μP monitors the probe position until the desired position ± 1 mm is reached. It then sends a command to the probe motor via the Probe Position Control Unit to stop.

4) The μP sends a command to the oscilloscope to make a horizontal sweep via the external trigger on the time base.

5) The μP samples the current and voltage characteristics of the Langmuir probe. It takes 100 time samples of each. The current and voltage characteristics are available from the Langmuir Probe Sweeper which requires the external sweep from the oscilloscope and which is connected to the Langmuir probe. The Langmuir trace itself can also be displayed on the oscilloscope.

6) After the 100 samples have been acquired the μP searches for a knee in the Langmuir trace. If the knee comes before the 50'th sample, the μP rejects the data and prints the message "Number of valid samples less than 50". It then sends a command to the oscilloscope to perform another sweep and reacquires the new data. It is up to the operator at this point to readjust manually the offset on the Langmuir Probe Sweeper to ensure that the knee comes after the 50'th sample.

7) In order to ensure that there is enough dynamic range in the data to perform a valid derivative that is not limited by quantization errors, the μP eliminates the first N samples in which the difference between samples is not at least 10 times the least significant bit. It then checks to see if there are at least 25 remaining samples until the knee of the Langmuir trace. If there are not then the μP prints the message "Number of valid samples less than 25". It then sends a command to the oscilloscope to perform another sweep and reacquires the new data. It is up to the operator at this point to readjust manually the gain of the Langmuir Probe Sweeper to ensure that there is enough dynamic range in the data. This change of gain should be noted on the printout because the density values must then be adjusted.

8) After the μP determines that the data is valid it computes the electron density, the electron temperature and the plasma potential and prints them. It also prints the probe position and the number of valid samples. All data printed is also displayed on the television for operator convenience. The computation algorithm is given in Appendix B.

9) The μP increments the desired position and returns to step 1. Usually, the next desired position of the probe is 5 - 10 cm further along the axis of the chamber so that a density profile is typically generated.

10) The μP stops after the desired number of steps specified in the initialization procedure.

APPENDIX A

Initialization

I Hardware diagram

A detailed diagram of the microprocessor box is given in Figure 2. The microprocessor was originally used as a development model and many of the switches are redundant or inoperative in the present configuration. There are three front panels of input-output and control connections. These will be described from left to right.

1) The first panel consists of 4 BNC connectors which are inputs to the analog data acquisition system. This consists of a Datel MDAS-16 connected to a Peripheral Interface Adapter (PIA) which allows up to 16 multiplexed input channels to be addressed by the microprocessor. The A/D converter inside the MDAS-16 has 12 bits of resolution and accepts signals of $\pm$ 10 volts. Input channel No 1 is in the lower left hand corner and is labeled POSITION. This should be connected to the PROBE POSITION BNC of the Probe Position Control Unit. Input channel No 2 is labeled VPROBE and should be connected to the SWEEP OUT BNC of the Langmuir Probe Sweeper. Input channel No 3 is labeled IPROBE and is connected to the PROBE CURRENT OUT BNC of the Langmuir Probe Sweeper. Input channel No 4 is not used.

2) The second panel consists of the peripheral control input-output connectors. There is a switch which can be up in the PAPERTAPE position or down in the KEYBOARD position. This should always be in the KEYBOARD position except immediately before loading a papertape.

The BNC output labeled TRIGGER should be connected to the oscilloscope trigger input. The sockets are labeled 1-5 in Figure 2 but are not labeled on the panel. From Figure 2, however, they are identifiable, Socket No 1 should be connected to the Probe Position Control Unit. Socket No 2 is a MIKBUG (see Appendix C for a description of MIKBUG) printer output and not used. Socket No 3 is the printer PIA output and should be connected to the printer. Socket No 4 is the papertape reader input and should be connected to the JI socket on the Decitek papertape reader. Socket No 5 is the Keyboard input and should be connected to the keyboard.

3) The third panel consists of three rows of switches and buttons. Only the top row is operative. The first switch from the left controls the source of the TV display information. If the switch is up (MIKBUG) then the TV display is controlled by MIKBUG. If the switch is down (PGM) then the TV display is controlled by the user's program. The second switch should always be up. The third switch should always be down. The fourth switch controls a lock on the Random Access Memory cards. If the memory is to be locked (by a separate switch on the cards) the switch must be down. The memory is always unlocked if the switch is up. These locks are convenient when debugging and modifying programs since often one wants to protect the program in the Random Access Memory from inadvertant erasure or modification.

The first button is a reset button which initializes the microprocessor and restores control to the MIKBUG program. The second button clears the TV display. It must be pushed twice and is only operative after the reset button is pushed. The third and fourth buttons are inoperative.

The power on/off switch in the lower right hand corner is inoperative. Instead the dc power enters the rear panel from a separate supply.

There are twelve cards inside the microprocessor box. From left to right they are:

a) Analog data acquisition MDAS-16
b) Input-output
c) Microprocessor M6800
d) Input-output
e) Random Access Memory 2K
f) Random Access Memory 2K
g) Random Access Memory 8K
h) Programmable Read Only Memory 8K
i) Random Access Memory 8K
j) Input-output
k) Input-output
l) Input-output

All the memory cards can change slots and their addresses are variable. However only cards, g. h, and i are easily accessible. There are spare memory cards available for expansion or replacement. The back panel of the box consists of two power inputs which come from the power supply directly above the μP box and one TV output which is connected to the Television Display.

II Program initialization

After the hardware connection are made as described in Section I, the power should be turned on. The following sequence will initialize the program described in the main body of the text.

1) Push reset button
2) Push clear TV display button (twice)
3) Put switch No 1 in up position
4) Put the switch KEYBOARD/PAPERTAPE in the KEYBOARD position
5) Unlock at least the memory 0 → 2K. This can most simply be done by unlocking all the memory with switch No 4.
6) Load the starting address 2400 into memory locations A048 and A049 (see MIKBUG)
7) Put switch No 1 in the PGM position
8) Push G on the keyboard

The program should now begin execution with a series of interactive questions and responses. The μP assumes that one wishes to move the probe to an origin and then move it down the chamber in equal size steps measuring the density and temperature at each point. A typical interrogation and response goes as follows. The operator's responses (typed on the keyboard) are underlined.

```
1)   ORIGIN                  =  0000  MILLIMETERS
2)   LENGTH OF ONE STEP      =  0050  MILLIMETERS
3)   NUMBER OF STEPS         =  0080
4)   ARE THE PROBE CONSTANTS THE SAME ?  0000 = YES   0001 = NO   0001
5)   INPUT PROBE CONSTANTS
6)   MU                      =  4.88000 E-003
7)   NU                      =  2.80000 E-003
8)   PRBCON                  =  1.20000 E+010
9)   COMPUTER TEST CASE
10)  ELECTRON TEMPERATURE    =  8.53825E-002 ELECTRON VOLTS
11)  PLASMA DENSITY          =  5.63443E+011
```

Questions and responses 1, 2, and 3 are obvious except for the fact that there is a switch on the Probe Position Control Unit, which reduces the analog voltage constant proportional to the probe position by a factor of 2. If this switch is thrown from 4.88 mV/mm to 2.44 mV/mm and if one wants an origin of 1000 mm, then it is necessary to type in 0500 for the ORIGIN. And similary if one wants a step size of 50 mm, it is necessary to type in 0025.

Line 4 asks if the probe constants are the same as the previous case. This is usually true and the response 0000 is given. The μP then skips to line 9.

The response 0001 is given if: the gain of the Langmuir Probe Sweeper is changed; the probe area is changed; at the beginning of the day; or one wants a printed record of the probe constants.

Line 5 requests new probe constants only if the response 0001 was given. The constant MU is the voltage equivalent of a least significant bit. This is almost never changed since the analog data acquisition system divides its dynamic range of 20 volts into 4096 steps. Thus one step equals $4.88 \cdot 10^{-3}$ volts and is given in line 6.

Line 7 asks for a constant proportional to the gain of the Langmuir Probe Sweeper. This is controlled by a three position switch plus a toggle switch on the Langmuir Probe Sweeper. These constants are given in table 1.

Line 8 asks for a constant that is proportional to the area of the probe and converts the calculated density result into the desired units of particles per cubic centimeter. For a probe a radius 1mm this constant is $1.2 \cdot 10^{10}$.

Line 9 announces that the computer is going to generate a test case which tests the arithmetic operations.

Lines 10 and 11 are the results of the test case calculations and can be compared with previous cases to determine if the system is functioning correctly.

If at any time during the questions and responses, a wrong response is given, then the operator must push the reset button and the G key on the keyboard to restart.

III Probe Position Control Unit

After the test case is finished, the μP sends a command to the Probe Position Control Unit to move the probe to the origin. The AUTOMATIC/MANUAL switch of the Probe Position Control Unit must be in the AUTOMATIC position. If it is foreseen that the probe position will exceed 2000 mm, then the position constant should be set to 2.44 via the front panel switch. This will mean that all probe position printouts must be multiplied by 2 to have the correct value.

IV Langmuir Probe Sweeper

The gain should be set so that the knee has at least a value of two volts and so that the singal does not exceed 10 volts anywhere. The knee should be near the eighth division from the left hand edge of the oscilloscope.

V Oscilloscope

The sweep time should be 20 ms/div and the external trigger should be divided by 10 to provide noise immunity. The last point sampled by the μP is just off the screen.

APPENDIX B

The microprocessor calculates the electron temperature and density by assuming that the current to the probe is given by

$$I = \frac{n_o e A\overline{V}}{4} e^{-e\phi/kT} \qquad (1)$$

where n_o is the electron density, e is the electron charge, $\overline{V}$ is the mean thermal speed = $\sqrt{\frac{8kT}{\pi m_e}}$, A is the surface area of the probe, ϕ is the potential on the probe measured from the knee in the Langmuir trace, T is the electron temperature and k is Boltzmann's constant.

By noting that

$$\frac{I}{\frac{dI}{d\phi}} = \frac{-kT}{e}, \qquad (2)$$

the electron temperature can be calculated by computing the derivative of the current at each point and dividing it into the current. This is a simple procedure numerically but produces a somewhat noisy result. The noise is reduced to about 1% by averaging the temperatures calculated over all the valid samples.

A valid sample is further restricted from that defined earlier in that the three samples just below the knee are also rejected to avoid the rounding of the knee as seen experimentally.

Given the electron temperature, the electron density can be determined from Eq. (1) at $\phi = 0$ (i.e. at the Langmuir knee). The identification of the knee is given by seeking the maximum negative second derivative of the current with respect to voltage.

The above numerical methods have been checked with the usual graphical or "eyeball" methods and found to be accurate. What is perhaps more important is that they are much more consistent, repeatable and, of course, take much less time.

APPENDIX C

MIKBUG

MIKBUG is a Motorola copywrighted software program which can be considered as a tool which can load, modify and execute other programs. When the microprocessor is turned on and the reset button is pushed then the machine begins to run the MIKBUG program and waits for an operator's command. A complete description of this program is available.[1] In order to execute a user program, the following information is sufficient.

1) In order to change a memory location, type M, then the address, then the space bar, and then the new value. For example, typing M, A, 0, 4, 8, SPACE BAR, 2, 4 changes whatever was in the location A048 to the value 24. After the above instruction MIKBUG assumes that you want to also change the next memory location, i.e. A049. If this is the case then the space bar must be pushed and the new value then given. For example, SPACE BAR, 0, 0 loads 00 into location A049. If this is not the case and you wish to do some other task then space bar must be pushed followed by any non-hexadecimal character.

2) In order to execute a program, place the beginning address of the program in the memory location A048 and A049 and then type G.

3) The beginning address of the Langmuir probe program is at 2400.

TABLE 1

Knob \ Toggle	G = 50	G = 100
Counterclockwise	$4.03 \cdot 10^{-2}$	$2.02 \cdot 10^{-2}$
Neutral	$7.85 \cdot 10^{-3}$	$3.92 \cdot 10^{-3}$
Clockwise	$2.8 \cdot 10^{-3}$	$1.4 \cdot 10^{-3}$

References

{1} CRPP Electronic Library

Figure Captions

Fig. 1 : Block diagram of the microprocessor system

Fig. 2 : Front panel of the microprocessor

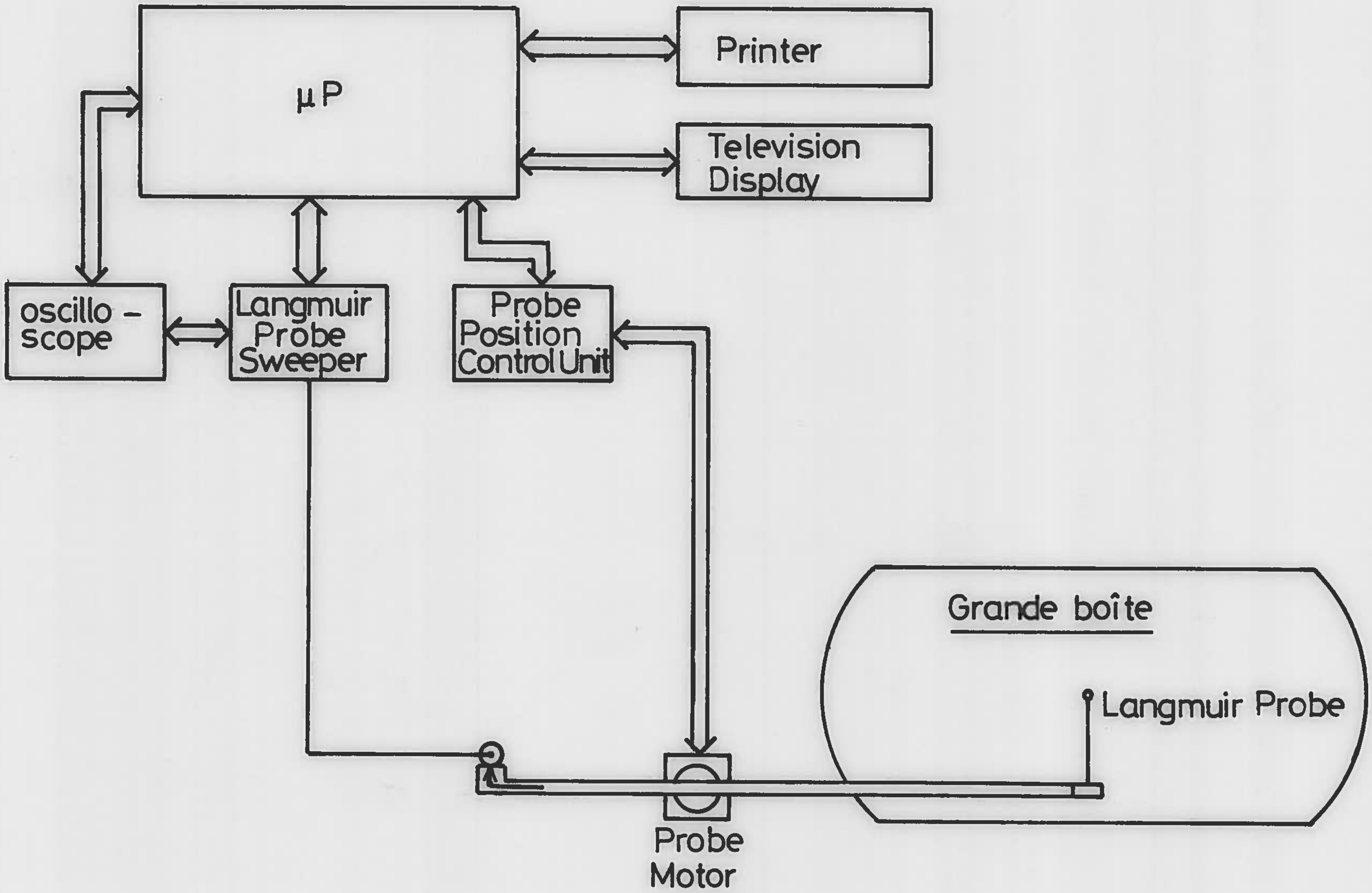
µP
Printer
Television Display
oscillo - scope
Langmuir Probe Sweeper
Probe Position Control Unit
Grande boîte
Langmuir Probe
Probe Motor

Figure 1

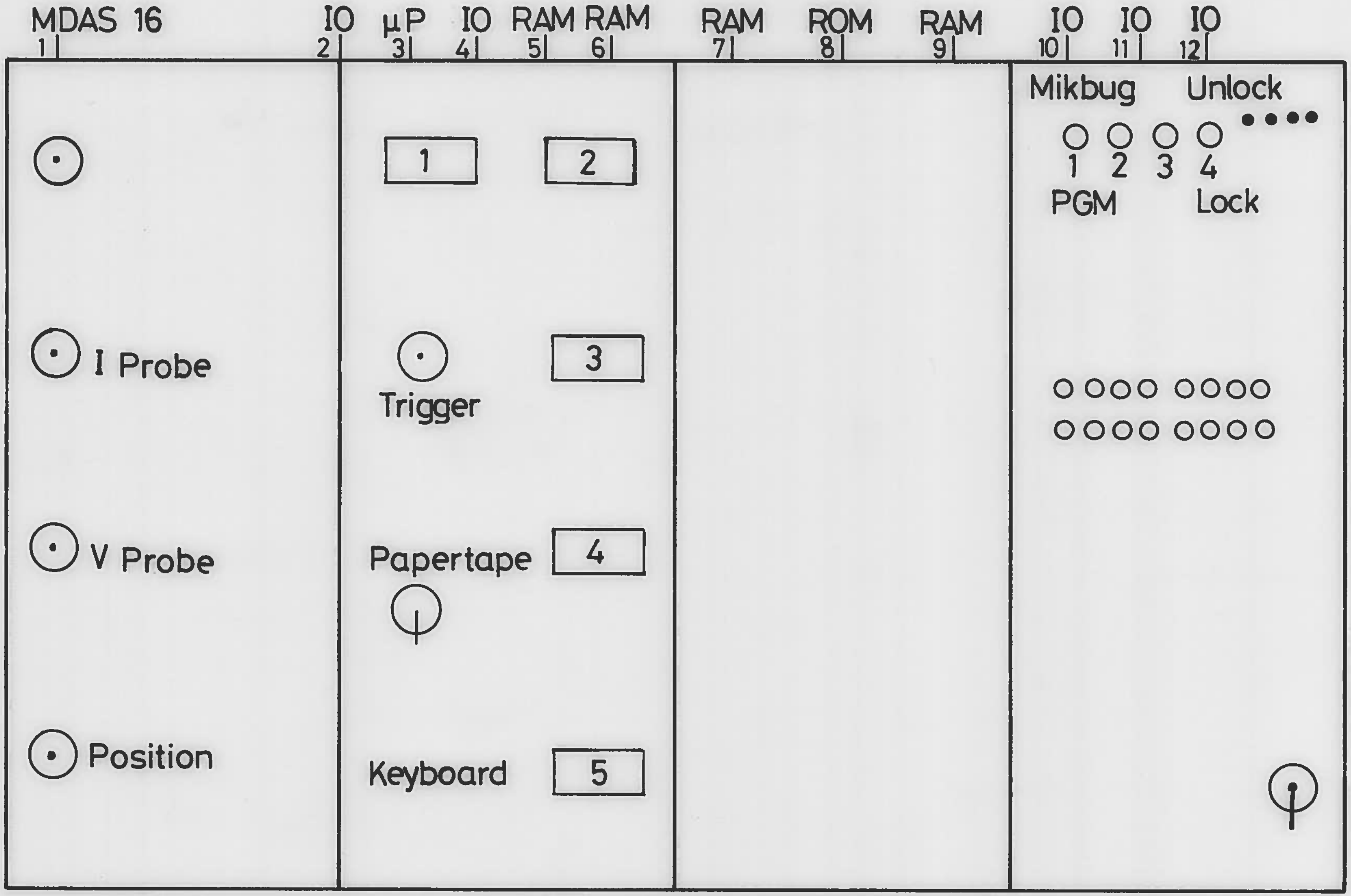
MDAS 16
1
IO
2
μP
3
IO
4
RAM
5
RAM
6
RAM
7
ROM
8
RAM
9
IO
10
IO
11
IO
12
I Probe
V Probe
Position
1
2
Trigger
3
Papertape
4
Keyboard
5
Mikbug
Unlock
1 2 3 4
PGM
Lock

Figure 2